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ABSTRACT

This second in a series of ten modules for a course titled Welding Inspection describes the key features of the oxyacetylene and shielded metal arc welding process. The apparatus, process techniques, procedures, applications, associated defects, and inspections are presented. The module follows a typical format that includes the following sections: (1) introduction, (2) module prerequisites, (3) objectives, (4) notes to instructor/student, (5) subject matter, (6) materials needed, (7) procedures, (8) data table, (9) reference materials, (10) test. (The course is one of fifteen technical courses for the second year of a two-year postsecondary curriculum in Nuclear Quality Assurance/Quality Control Technology.) (LRA)

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NUCLEAR TECHNOLOGY

COURSE 28 WELDING INSPECTION

MODULE 28-2 Shielded Metal Arc and Oxyacetylene Welding

CE 024 262

GENERAL PHYSICS CORPORATION
Columbia , Maryland

COURSE MODULES

COURSE 28 WELDING INSPECTION

Module 28-1	Welding Fundamentals and Processes
Module 28-2	Shielded Metal Arc and Oxyacetylene Welding
Module 28-3	Tungsten Inert Gas (TIG), Metal Inert Gas (MIG) and Submerged Arc Welding
Module 28-4	Weld Joint Verification
Module 28-5	Qualifications
Module 28-6	Process Controls
Module 28-7	Acceptance Inspection
Module 28-8	Filler Metal Control
Module 28-9	Weld Repair Control
Module 28-10	Records

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This module was prepared for General Physics Corporation by John Espy, General Physics Corporation, and Ben Selleck, Ben-Sel. Associates.

GENERAL PHYSICS CORPORATION

1979

INTRODUCTION

The Nuclear QA/QC technician frequently performs verification, monitoring, and inspection tasks related to oxyacetylene and shielded metal arc welding. Verifications include qualifications of procedures and welders and correctness of materials. Monitoring includes checks for compliance with welding procedures. Inspections include fit-up and final weld inspections.

The oxyacetylene and shielded metal arc welding processes are two widely employed methods of joining metallic parts. Their equipment is relatively inexpensive and transportable, thereby making these processes popular in welding shops and field welding applications. However, neither is well suited for automation and consequently, their welding speed is slow.

This module describes the key features of these two welding processes. The apparatus, process techniques, procedures, applications, associated defects and inspections are presented. The student/trainee should approach this module from the viewpoint of how each welding process makes (or fails to make) a sound weld. It will become evident that each process contains key features which if employed properly, can produce high quality weldments.

Knowledge of these welding processes should equip the student/trainee to understand the basis for the qualifications, process controls and inspection requirements presented in later modules of this course.

MODULE PREREQUISITES

The student/trainee should have prior training or experience on welding fundamentals. Completion of Module 28-1 of Nuclear Technology satisfies this prerequisite.

OBJECTIVES

Upon completion of this module the student/trainee can:

1. State the function of major equipment components of the oxyacetylene and shielded metal arc welding processes.
2. List the techniques employed by the welder and state their effects on the quality of the weld for each of the two welding processes.
3. Arrange given steps of an oxyacetylene or shielded metal arc welding procedure in correct sequence.
4. Describe effects of given essential variables of the two welding processes on weld quality.
5. Identify potential sources of given defects and state how these sources can cause the defect.
6. List the types of defects that can be detected with a given type of inspection and briefly describe the method of detection.

OXYACETYLENE WELDING

Equipment

Heat from oxygen-fuel gas combustion offers a convenient means of welding. The necessary equipment is portable and requires no external power source, such as electricity. Hydrogen, natural gas, propane and other fuel gases may be used as the fuel gas, but acetylene is most commonly used, due to its high heating capacity. The oxyacetylene flame provides for fusion and shielding simultaneously. Filler material is fed separately into the flame.

Basic equipment needed for the oxyacetylene welding process is shown in Figure 28-2-1.

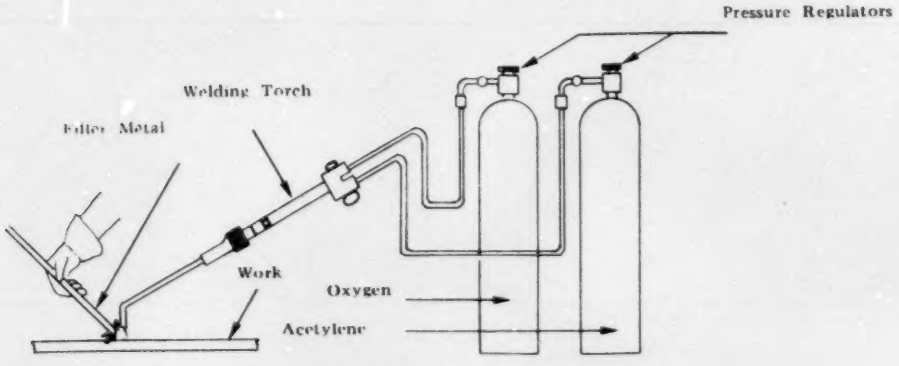


Figure 28-2-1. Equipment for Oxyacetylene Welding

When using oxyacetylene welding equipment, one safety precaution should always be observed: THE GAS BOTTLES SHOULD ALWAYS BE CONSTRAINED BY CHAIN OR BELT STRAPPING TO PREVENT TIPPING THEM OVER. If the connections at the neck

of the bottles are broken, the escaping pressurized gas makes the bottle become a projectile, capable of damaging equipment and injuring personnel.

Process Techniques

For oxyacetylene welding, oxygen and acetylene are fed, individually, through pressure regulating valves, through hoses and into the welding torch. As shown in Figure 28-2-2, the welding torch consists of a mixing section and a tip. While the primary adjustment for gas flow is made by setting the pressure regulating valves, the needle valves on the mixing section can "fine tune" the flame. Torch size determines heating capacity. Larger torch sizes permit greater volume of gas flow and, consequently, larger heating capacity.

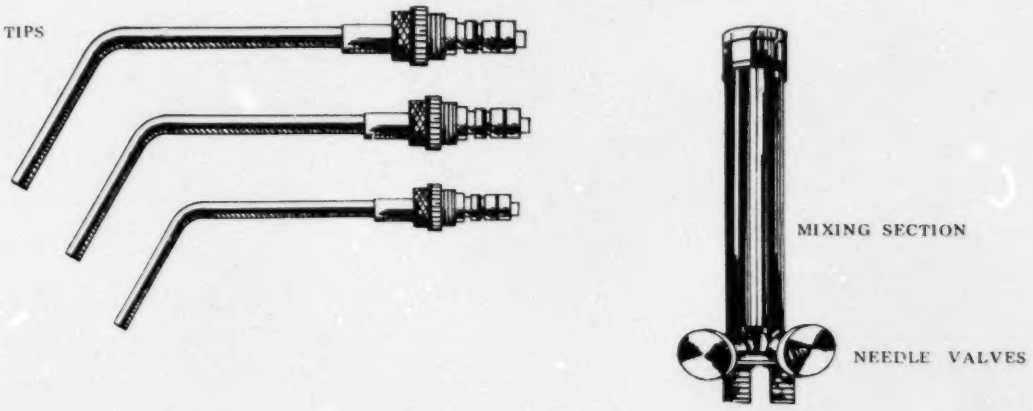


Figure 28-2-2
Oxyacetylene Welding Torch

Varying the amount of oxygen and fuel gas in the gas flowing to the tip of the torch produces different welding atmospheres and different flame temperatures. The type of flame selected must be compatible with the base material to prevent the base metal from being adversely affected by the flame. Generally, the welder makes adjustments to the gas flow, based on the appearance of the flame. The welder is able to make these adjustments because, as the acetylene-oxygen mixture burns from the tip of the welding torch, several clearly recognizable zones of combustion appear. Figure 28-2-3 shows the conditions visible during adjustment of the oxyacetylene flame and identifies that three types of flames are possible. These are neutral, carburizing and oxidizing flames.

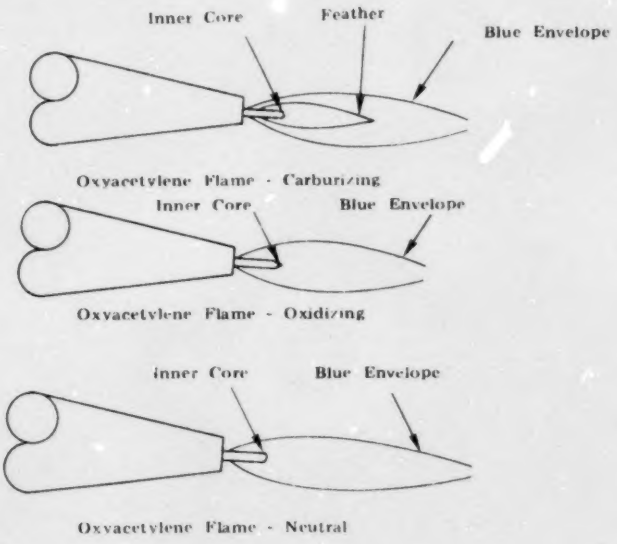


Figure 28-2-3
Conditions of Oxyacetylene Flames

Neutral Flame

The neutral flame appears when equal amounts of oxygen and acetylene are burning. A neutral flame does not react with the metal. When the flame is neutral, neither excess acetylene nor excess oxygen are present at the tip of the inner cone. A neutral flame can be obtained by careful observation of the size and color of the combustion zones in the flames, while adjusting the torch inlet valves. In a neutral flame, the pale blue inner cone is from 1/16 to 1 inch long, depending on the size of the torch; and it is sharply defined. The bluish outer envelope serves as shielding during welding.

Carburizing Flame

By increasing acetylene flow in excess of oxygen flow, a third zone appears which is termed "feather" or "acetylene feather". The inner cone remains sharply defined and the bluish outer envelope exists. The length of the whitish feather is proportional to the amount of excessive acetylene flow and is measured in terms of the inner cone. If x equals the length of the inner cone and the feather is twice as long, a 2x feather exists. A 3x feather is three times as long as the inner cone and so on. Because the feather contains white hot carbon particles, this flame is called "carburizing". The carburizing flame scavenges oxygen, which could otherwise cause oxides and is typically employed in welding aluminum and steel and for hard-surfacing with nickel, chrome or cobalt alloys.

Oxidizing Flame

If oxygen flow is increased in excess of acetylene flow, an oxidizing flame results. The oxidizing flame has only two zones but, unlike the neutral flame the inner cone is shorter, necked on its sides, and becomes darker

blue or purplish. The outer envelope is more turbulent. The oxidizing flame is used for welding various grades of brass and bronze.

To begin oxyacetylene welding, the flame is applied to the base metal until melting occurs. Then, bare filler rod is fed into the flame where it melts and flows into the molten base metal. The angle of the torch is manipulated to control puddle flow. Both distance from the work piece and movement of the torch control heating rate, (given a fixed torch size). Movement of the torch is in small increments to permit the flame envelope to shield the molten puddle until resolidification occurs.

Welding Procedures

Written welding procedures prescribe the specific materials, equipment, and techniques that the welder must use. The welding procedure is based on previous successful use in production welding or in welding qualification test pieces. It provides a technically acceptable method of standardizing welds that are produced, controls the quality of the weld, and helps to ensure defect-free welds.

There is a separate welding procedure for each group of similar joints. The welding procedure lists variables that provide instructions to the welder. These variables are sub-divided into two categories: essential and non-essential. Those that establish the limit of qualification of the procedure are called essential variables. The remaining variables are called non-essential. Both types are necessary for a quality weld. Welding codes establish the essential and non-essential variables for each welding process. Table 28-2-1 lists typical essential and non-essential variables for the oxyacetylene welding process. (If Table 28-2-1 were an actual welding procedure, specific values or types of gas or materials would be inserted.)

TABLE 28-2-1, PROCEDURE VARIABLES FOR OXYACETYLENE WELDING

Fundamental Variables	Essential Variables	Nonessential Variables
1. Joint Design	(none)	(a) groove type & design (b) use of backing (c) material type of backing
2. Base Metal	(a) material type (b) joint thickness	None
3. Filler Material	(a) material type (b) deposited weld metal chemical composition	(a) size of bare rod
4. Position	(none)	(a) the welding position to be used
5. Preheat	(none)	(a) the minimum preheat temperature to be maintained
6. Postweld heat Treatment	(a) heat treatment temperature	(none)
7. Gas	(a) type of fuel gas	(none
8. Technique	(a) for hard surfacing only, oxygen and acetylene pressures and torch size.	(a) stringer or weave bead (b) nature of flame (neutral, carburizing, or oxidizing) (c) forehand or backhand (d) method of initial and interpass cleaning

Essential and Non Essential Variables

The decision to classify a variable as essential or nonessential depends primarily on the effect the variable would have on the physical strength of the weld joint. This decision is also based on the advantages and disadvantages of the welding process. It assumes that the welder is doing to follow the given welding procedure and assumes that the welding engineer specifies welding processes and joint designs that are compatible.

Notice in Table 28-2-1 that joint design and position are considered nonessential variables in oxyacetylene welding; this is because oxyacetylene welding is adaptable to all joints in all positions. On the other hand, material type and thickness, deposited weld metal chemical composition, heat treatment temperature, and type of fuel gas are essential variables. These variables affect such things as weldability, heating rate, and weld strength.

Once a welding procedure is qualified, it may be used in any application where essential variables remain the same. However, if one or more essential variables must be changed in order to adapt the welding procedure to a specific joint, the revised procedure must be requalified by welding and testing a special qualification test piece.

Oxyacetylene Procedure

The oxyacetylene welding procedure covers the essential and non-essential variables listed in Table 28-2-1. The procedure establishes joint fit-up requirements and the welding techniques to be employed.

As with all welding processes, the weld joint needs to be clean. Foreign materials (such as oil, dirt, chips, scale) will typically vaporize or melt in the weld puddle, thereby increasing risk of porosity and inclusions.

Welding procedures typically specify the method of cleaning and the cleanliness acceptance criteria to be applied immediately prior to commencement of welding. The procedure will also specify interpass cleaning method to assure clean surfaces between passes. The oxyacetylene welding process produces a relatively clean weld bead and requires little interpass cleaning.

Penetration (depth of melting of base metal) is governed by torch size and welder's techniques since the combination of these two variables establishes the heating rate. Joint welding by oxyacetylene requires relatively deep penetration which is obtained by the welder's techniques. Hard surfacing by oxyacetylene requires relatively shallow penetration to give a resultant weld bead whose surface is essentially comprised of the hard filler material. Therefore, for hard surfacing, the torch size and associated gas pressures become essential variables.

Application

Oxyacetylene welding can be universally applied. However, because its weld metal deposition rate is low, compared to other welding processes, it is mostly used where other welding processes have serious disadvantages. For example, welding of copper and aluminum base alloys is easier with oxyacetylene welding than with most of the electric arc processes. Oxyacetylene gives the high heating rate and precise control of the heating rate needed for these alloys. Also, depth of penetration is easily controlled by the oxyacetylene welding process which makes it especially suitable for small parts in the overhead and vertical position.

Characteristic Defects; Their Causes and Detection

Defects most likely to occur with the oxyacetylene welding process are listed in Table 28-2-2 along with their causes and means of detection.

Table 28-2-2

Characteristic Defects For Oxyacetylene Welding

DEFECT	PROBABLE CAUSE	DETECTABLE BY
Undercut	Insufficient addition of filler material; insufficient number of passes.	Visual inspection; radiography.
Burn Through	Torch too large; holding flame in one area too long.	Visual inspection; radiography.
Porosity	Oxidizing flame; too sudden removal of flame envelope.	Liquid penetrant or magnetic particle for surface; radiography for subsurface.
Crack in the weld metal	Torch too large; incorrect filler material; incorrect base metal.	Liquid penetrant or magnetic particle for surface; radiography or ultrasonic for subsurface.
Underbead Crack	Torch too large; Insufficient preheat.	Radiography or ultrasonic.
Incomplete Fusion	Joint inaccessability; improper control of torch angle.	Radiography or ultrasonic.

Undercut and burnthrough are visually discernable; therefore, visual inspection of the completed weld suffices for detection of undercut and burnthrough if both sides of the weldment are visible. If the inside is not accessible for visual inspection, radiography can be used.

Porosity and cracks may be open to the surface or completely sub-surface. Either liquid penetrant or magnetic particle testing has the capability to detect porosity and cracks that are open to the surface. Liquid penetrant tests employ a colored or flourescent fluid, that penetrates openings to the surface and a subsequent developing technique that attracts the penetrant from the openings. For any areas in which the developer pulls penetrant from openings, a color contrast is visible, which indicates the defect. For example, red penetrant attracted by white developer would show red rounded indications if porosity were present and red linear indications if cracks were present. To detect defects, magnetic particle testing induces a magnetic field into the weldment. Porosity and cracks disrupt the magnetic field. When magnetic particles are sprinkled onto the weldment, the magnetic particles concentrate at the points of disruption of the magnetic field and thereby show the defect. Radiography detects subsurface porosity and cracks. X-ray, or gamma rays, are directed at the weldment, toward film preplaced on the opposite side of the weldment. A percentage of the x or gamma rays pass completely through the weldment and darken the film. In areas where porosity or cracks are present, more rays pass through the weldment because there is less weld metal to absorb the rays. In these areas, greater darkening of the film will occur. When the film is developed, porosity shows up as a rounded dark area; cracks show up as linear dark areas. Ultrasonic testing can also be used to detect cracks. In this test method, ultrasonic sound waves are directed through the weldment. If cracks are present, the sound waves reflect back from the crack to a sensor

where the reflected signal is amplified and displayed on an oscilliscope or recorder. Ultrasonic testing also detects gross porosity in the same manner but is not sufficiently sensitive to detect fine porosity.

Underbead cracks and incomplete fusion can be detected by either radiography or ultrasonic testing. Techniques are the same as those used for detecting cracks in the weld metal.

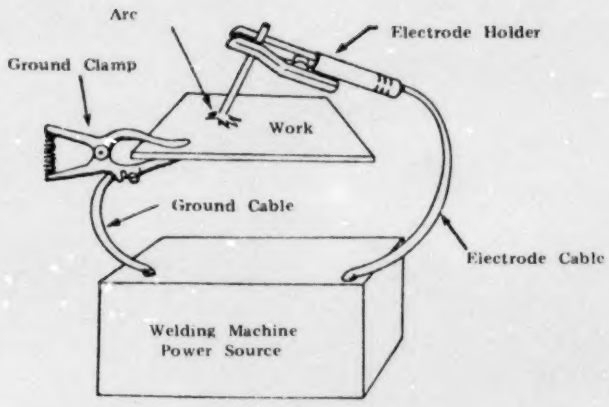
The specific inspections for welds made by oxyacetylene welding depend on the acceptance criteria specified for the weldment. Considering such factors as strength requirements and stress the weldment will see in service, the design engineer determines the types and sizes of defects which do not permit satisfactory service by the weldment. For example, if only cracks, undercut and burn through are of concern, adequate inspection can consist of visual inspection and radiography or if the backside of the weld is accessible, visual inspection and ultrasonic testing are adequate.

SHIELDED METAL ARC WELDING

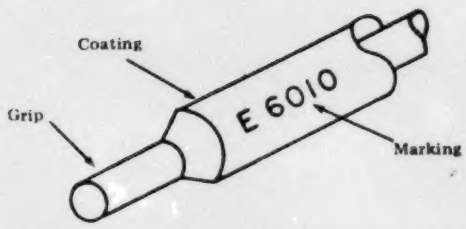
Equipment

The shielded metal arc welding process (SMA) produces heat for fusion by an electric arc between a coated electrode and the work. The coated electrode provides filler material and shielding. An electrical power supply provides current and voltage for maintaining the arc.

Basic equipment needed for shielded metal arc welding are shown in Figure 28-2-4



(a) Apparatus



(b) Electrode

Figure 28-2-4
Apparatus for SMA

The power supply provides voltage and current in one of several modes. Direct current, i.e., current flow in only one direction, is typically used, although alternating current, i.e., current that alternately changes direction of flow, can be employed for certain electrodes. The holder consists of an electrically insulated handle and vice type jaws for clamping the grip section of the electrode. Current flow path is completed by connecting the ground cable from the power supply to the weld joint to be welded. The coated electrode has the triple duty of providing arc, shielding and filler material.

Process Techniques

The events in and around the SMA arc are pictured in Figure 28-2-5.

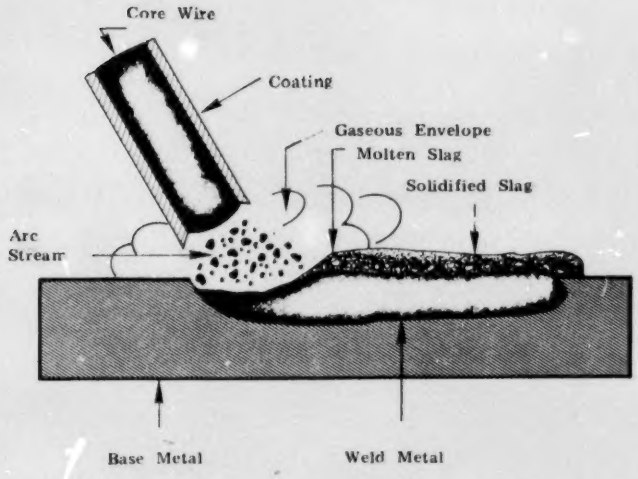


Figure 28-2-5
•SMA Process

Heat from the arc simultaneously melts the inner core wire, the electrode coating and some depth of base metal. Melting of the coating generates gases which displace air to provide shielding. Other portions of the coating form slag which floats on the weld puddle and whose trailing edge solidifies as the electrode moves along the weld joint. This slag shields the hot weld metal from oxidation. Also, most coatings contain metallic ingredients which melt and coalesce with the weld puddle. Such ingredients help achieve the desired chemistry of the weld metal. However, almost all of the filler metal comes from the core wire. Tiny droplets of metal stream from the core wire and coalesce with the molten base metal.

Pentration (depth of base metal that is melted) is dependent on a number of factors. The primary factor is

the current density in the arc which is a function of current and diameter of the coated electrode. Penetration increases as current is increased given a constant diameter electrode. Likewise, penetration increases as electrode diameter is decreased given a constant current value.

Penetration is also affected by the polarity of direct current. Either straight polarity or reversed polarity may be used as shown in Figure 28-2-6.

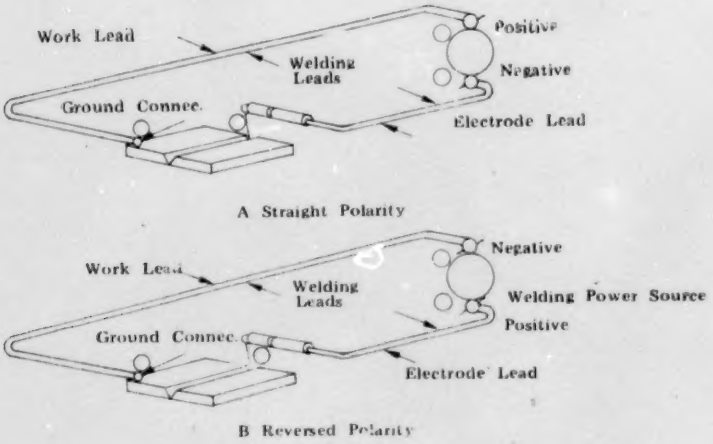


Figure 28-2-6
SMA Direct Current Polarity

The gases generated by melting of the electrode coating ionize in the arc. These gas ions aid current flow through the arc and tend to stabilize the arc, i.e., reduce whipping or turbulance in the arc. Since the positive gas ions cause more effect than negative ions due to their larger size, the direction of flow of the positive ions is important. With straight polarity as shown in Figure 28-26a, positive gas ions flow against the stream of core wire droplets toward the negatively charged electrode. This flow causes some flare in the arc and

imparts energy against the flow of core wire droplets. Consequently, less penetration occurs with straight polarity for a given combination of current and electrode diameter. The opposite occurs with reversed polarity. The flow of positive ions toward the negatively charged work piece tends to keep a cylindrical arc and add energy to the stream of core wire droplets. Thus, more penetration occurs with reversed polarity for a given combination of current and electrode diameter.

Arc voltage primarily determines the stability of the arc. The voltage is set at the welding power supply to a value which gives a stable arc with a given combination of current and electrode diameter. Within this power supply setting, arc voltage will vary with the arc length maintained by the welder. As SMA welding progresses, the welder continuously feeds the electrode into the arc, moves the arc along the weld joint, and controls weld puddle shape and flow by the angle of the electrode. With these three motions, the welder attempts to maintain a constant arc length in order to maintain proper arc voltage.

The effects of arc length on arc stability are illustrated by Figure 28-2-7

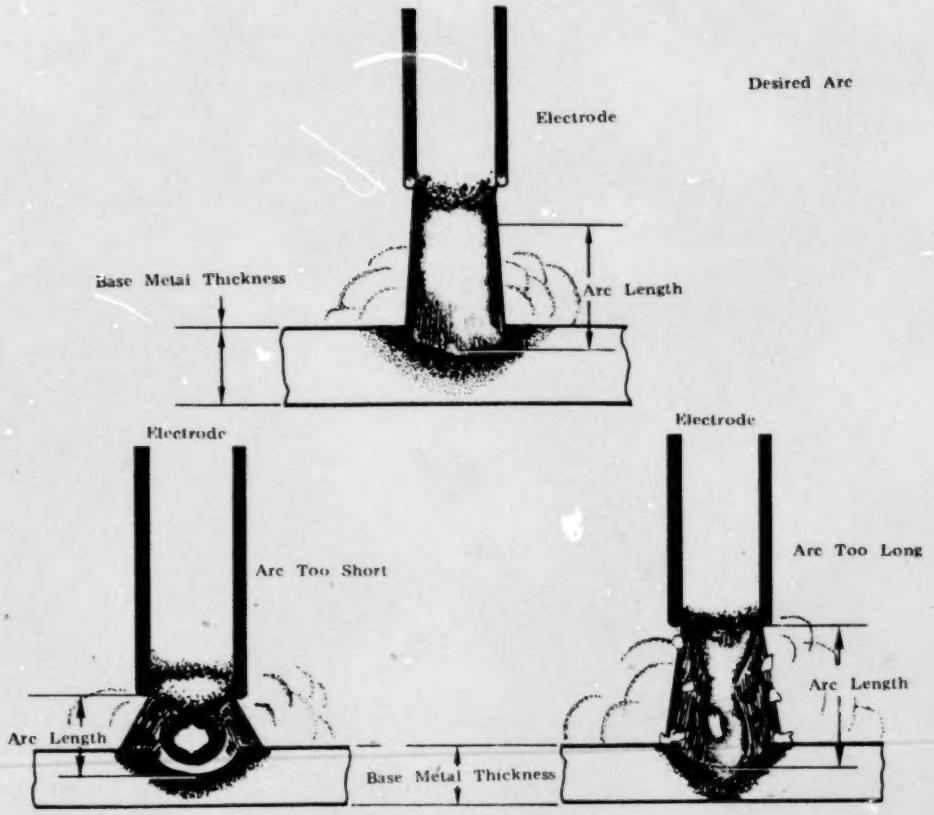


Figure 28-2-7
SMA Arc Length Variations

Arc length that is too short results in more pentration and a more narrow and raised weld bead. Arc length that is too long results in less penetration and a wider and flatter weld bead. In either case, the arc tends to become unstable. Arc turbulance can cause inadequate shielding resulting in porosity in the weld. Arc turbulance also increases weld spatter. Weld spatter always occurs to some extent with shielded metal arc welding.

It consists of droplets of molten metal sprayed from the arc to surrounding areas. Such spatter that attaches to the base metal causes localized hard spots which must be removed in many welding applications to prevent crack initiation from the hardened area.

SMA Procedure

Table 28-2-3 lists typical essential and nonessential variables for the shielded metal arc welding process. SMA welding procedures give specific values for each variable.

These variables for SMA welding are classified as essential or nonessential using the same rationale as that described for the oxyacetylene welding process.

Interpass cleaning becomes particularly important for shielded metal arc welding. Slag formed by melting the electrode coating adheres to the solidified weld bead and must be removed prior to welding the next pass. A chipping hammer will normally loosen the slag such that a wire brush will sweep it from the weld. Grinding may be required along the edges of the weld bead and at the stops.

Angle of electrode is not listed in Table 28-2-3 because the angle is most favorable to complete fusion and good bead contour. In multi-pass SMA welding, the welder controls bead contour to avoid generating crevices where slag can be entrapped. If necessary, the welder will grind between passes to open crevices.

Maxium interpass temperature is an important variable when welding alloys susceptible to formation of undesirable grain structure when cooling is excessively slow. The SMA welding process has the capability of continually increasing base metal temperature when there are short time intervals between passes.

Table 28-2-3

Procedure Variables for Shielded Metal Arc Welding

FUNDAMENTAL VARIABLE	ESSENTIAL VARIABLES	NONESSENTIAL VARIABLES
1. Joint Design	(None)	(a) groove type and design (b) use of backing
2. Base Metal	(a) material type (b) joint thickness	(None)
3. Filler Material	(a) filler material type (b) deposited weld metal chemical composition	(a) diameter of electrode
4. Position	(a) where impact properties are tested, the welding position to be used	(a) for all other applications, the welding position to be used.
5. Preheat	(a) the minimum preheat temperature to be maintained (b) where impact properties are tested, the maximum interpass temperature permitted	(a) whether preheat is to be maintained after welding prior to post weld heat treatment (b) maximum interpass temperature
6. Post Weld Heat Treatment	(a) heat treatment temperature and time	
7. Electrical Characteristics	(a) where impact properties are tested, the current type (DC or AC), polarity (straight or reversed) and value (amperage) also, voltage	(a) for all other applications current type and polarity (b) current and voltage values
8. Technique	(a) where impact properties are tested and for vertical welds, the vertical progression (up or down)	(a) stringer or weave bead (b) method of initial and interpass cleaning (c) method of backgouging (d) use of nonmetallic retainers (e) vertical progression (f) whether manual or semi-automatic

Where the procedure specifies a maximum interpass temperature, the welder ensures sufficient cooling has occurred prior to welding the next pass.

Procedural Sequence

Procedural steps are arranged to give instruction on (1) requirements prior to welding (2) requirements during welding and (3) requirements after welding. Requirements prior to welding pertain to cleanliness and fitup of weld joint members. Requirements during welding are the specific welding parameters and techniques to be used by the welder. Requirements after welding are those pertaining to post weld heat treatment and acceptance inspection. A sample SMA welding procedure is given by Figure 28-2-8.2-8. It is noted that the backing ring in the sample procedure is of the same material as the base material. This means that good penetration and fusion of the backing ring will occur. This is typical of situations where backing rings are left in place. Where backing rings are removed after welding, they may be of an alloy which has a considerably higher melting point such that poor fusion of the backing ring occurs. This would make removal of the backing ring easier.

ABC Company

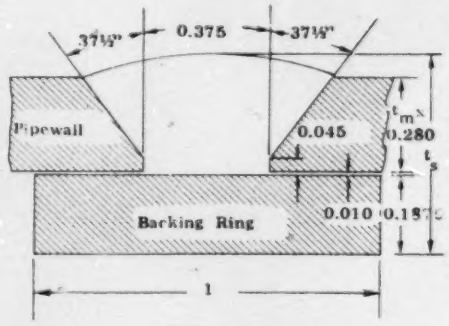
SMA Welding Procedure 101	Revision A	8/23/79

Joint Design and Fit-up

- joint design: double V butt with backing ring
- base material:
  - pipe: six inch schedule 80, alloy 715 copper - nickel per SB-466
  - backing ring; alloy 715, copper nickel per SB-171
- fit up dimension: per sketch #1

Welding Paramenters

- process manual sheilded metal arc
- filler metal: ECuN: coated electrodes per AWS A5.6
- welding current; direct current, reverse polarity
- preheat: none
- interpass temperature 150°F ,maximum
- post weld heat treatment: none
- welding data:

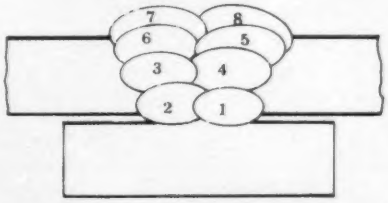


PASS NO.	WELDING PROCESS	ELECTRODE DIAMETER	CURRENT RANGE	ARC VOLTAGE
1&2	SMA	1/8	100-110	22-23
remainder	SMA	5/32	120-150	24-25

Figure 28-2-8
Sample SMA Welding Procedure
(Sheet 1 of 2)

Techniques

- position: flat (rotate with positioner to maintain flat position)
- bead technique: stringer bead
- sequence: per sketch # 2



- arc length: as short as practicable during welding and weaving shall be held to a minimum.
- angle of electrode: the electrode shall be inclined 15^0 to 20^0 from the perpendicular in the direction of travel during the complete welding operation (backhand technique)
- grinding: all starts and stops shall be ground to a minimum 1000 rms finish and the edges of the weld shall blend smoothly into base metal.
- interpass cleaning: hand slag pick and wire brush. Remove all visible slag.

Procedure

- detergent clean parts to remove any oil, chips, dirt or scale; water rinse.
- fit-up per sketch #1
- weld passes 1 and 2
- liquid penetrant test root
- weld passes 3 through 8
- grind
- liquid penetrant test final surface
- radiograph completed weld

Figure 28-2-8

Sample SMA Welding Procedure
(Sheet 2 of 2)

Application

The shielded metal arc welding process can be used for welding most of the alloys employed in a nuclear power plant. It is used most extensively for joining various types of steels, including the stainless steels, and for joining nickel alloys. It is used less extensively for joining copper and aluminum alloys. Shielded metal arc welding can be used in all positions and is, therefore, frequently used where the weld joint cannot be rotated and where it is either impractical (due to space limitations) or uneconomical to set up equipment for other electric arc welding processes.

Characteristic Defects and Their Causes

Defects most likely to occur from shielded metal arc welding are listed in Table 28-2-4 along with their probable causes and means of detection.

The shielded metal arc welding process can give all the defects associated with the oxyacetylene welding process and the additional defects of slag inclusions, weld spatter and arc strikes. The slag produced by the electrode coating normally floats on the weld puddle and is removed by interpass cleaning. Such slag can become entrapped if insufficient energy is applied to give time to float the slag or if physical recesses are created by excessive weaving, improper bead sequencing or improper electrode angle. Weld spatter always occurs with SMA but is exacerbated by improper arc length or excessive current. Arc strikes can result in localized hard spots which can initiate cracks. Spatter and arc strikes are removed by grinding.

Table 28-2-4

Characteristic Defects for Shielded Metal Arc Welding

DEFECT	PROBABLE CAUSE	DETECTABLE BY
Undercut	Improper electrode angle; insufficient number of passes	visual inspection; radiography
Burnthrough	excessive current; electrode diameter too large (excessive heating rate)	visual inspection; radiography
Porosity	improper arc length; moisture in electrode coating; foreign particles (dirt)	surface: liquid penetrant or magnetic particle subsurface: radiography
Slag Inclusion	excessive weaving; improper bead sequence; current low for electrode diameter; inadequate interpass cleaning	radiography
Incomplete Fusion	current too low; excessive weaving	radiography or ultrasonic testing
Crack in the Weld Metal	excessive current; incorrect base metal; incorrect filler material; moisture in electrode coating	surface: liquid penetrant or magnetic particle subsurface: radiography or ultrasonic
Underbead Crack	Excessive current; insufficient preheat	radiography or ultrasonic
Spatter	some spatter will occur; excessive spatter is caused by improper arc length, excessive current or improper voltage	visual inspection or radiography
Arc strike (a burn on base metal from an electric arc)	erroneously striking coated electrode against base metal; dirty ground cable connection; frayed insulation permitting cable to arc against work piece	visual inspection

In addition to slag, the electrode coating introduces a new potential source of defects. Many alloys crack when subjected to hydrogen, stress, and temperature. To prevent hydrogen induced cracking, certain electrode coatings are constituted such that very little hydrogen exists in the shielding gases. Electrodes of this type are low hydrogen electrodes. However, electrode coatings absorb moisture from the atmosphere which decomposes into hydrogen and oxygen in the electric arc. Such moisture can cause both porosity and cracking in the weld metal.

Two precautions are taken to prevent porosity and cracking from moisture in electrode coatings. First, the electrode manufacturer bakes the electrodes to dry them and packages the baked electrodes in hermetically sealed containers. Secondly, weld shops bake low hydrogen electrodes shortly before use to drive out any absorbed moisture.

TECHNIQUES FOR COMPLIANCE CHECKS

Verbatim compliance with welding procedures increases the probability of making defect free weldments. To help assure verbatim compliance. QA/QC Technicians frequently observe welding in progress to determine if requirements are being met. Methods of checking welding requirements for fuel flame and electric arc welding processes are listed in Table 28-2-5.

Table 28-2-5 should be used in conjunction with the Procedures in this module. It is intended to offer basic methods for monitoring welding variables but not intended as an inspection procedure. Later modules of this course will describe the inspection of welding typically performed by QA/QC Technicians.

Table 28-2-5

Methods of Checking Welding Requirements

TYPE OF REQUIREMENT	METHOD OF CHECKING
Joint Design and Fit Up	Compare sketch of drawing referenced by welding procedure to the physical configuration of the weld joint. Measure required dimensions with mechanical measuring devices.
Base Metal Identification (Including Backing)	Compare marking on base metal with welding procedure requirements. If unmarked, compare material issue record entries with weld procedure requirements.
Filler Material Identification	Compare marking on filler material and physical appearance and size of filler material with weld procedure requirements.
Welding Position	Compare physical position of weld joint to weld procedure requirement.
Cleanliness	Visually observe for scale, oxides, dirt, oil, etc. Compare with welding procedure requirements.
Preheat and Interpass Temperature	For preheat, measure base material temperature within one inch of the weld joint with temperature indicating device (e.g., temperature melting crayons, contact pyrometer, thermocouple.) For interpass temperature, measure the weld joint temperature immediately prior to commencement of welding.
Gas Pressure	Compare gas pressure meter readings with weld procedure requirement.
Gas Flow	Compare gas flow meter readings with weld procedure requirement.
Nature of Oxyacetylene Flame	Visually observe flame through welder's goggles or hood; compare with weld procedure requirement.

Table 28-2-5 (Cont.)
Methods of Checking Welding Requirements

TYPE OF REQUIREMENT	METHOD OF CHECKING
Welder's Techniques (Bead, Forehand, Backhand, Angle of Electrode, Progression, Interpass Cleaning, Grinding, Back Gouging)	Visually observe the welder's practices; compare with welding procedure requirements.
Current Type and Polarity	Observe switch settings on the electrical power supply for AC or DC and straight or reversed; compare with welding procedure requirements.
Current	Read value or ammeter on power supply or clamp tong ammeter around one cable and read value (Note: welding must be in progress to read current or voltage); compare with welding procedure requirement.
Voltage	Read value on voltmeter on power supply or clamp tong voltmeter around one cable and read value; compare with welding procedure requirement.
Postweld Heat Treatment	Compare time-temperature chart with welding procedure requirement; ensure the chart represents the weld joint being checked.

EXERCISES

1. Enter specific instructional information on the oxyacetylene welding procedure outlined below and indicate for each entry whether it is an essential or nonessential variable:

Oxyacetylene Welding Procedure Outline	Instruction to Welder	Essential Nonessential
a. Joint Design		
b. Base Metal Type		
c. Filler Metal Type		
d. Welding Position		
e. Preheat (yes/no)		
f. Postweld Heat Treatment (yes/no)		
g. Fuel Gas		
h. Nature of Flame		

2. Complete the chart below by entering the probable cause of each defect from the oxyacetylene welding process and the inspection method capable of detecting the defect. More than one probable cause may be listed.

DEFECT	PROBABLE CAUSE	INSPECTION METHOD
a. surface cracks		
b. Incomplete fusion		
c. undercut		

3. For each application described below, list the minimum inspection to be made of the completed weld.

APPLICATION	MINIMUM INSPECTIONS
a. Oxyacetylene welding of a V-butt joint where cracks and underbead cracks are the only defects of concern	
b. Oxyacetylene welding of a V-groove corner joint where surface cracks are the only defects of concern.	

c. Oxyacetylene hardsurfacing of a flat surface where surface porosity and surface cracks are the only defects of concern.

d. Oxyacetylene welding of a V-groove tee joint where undercut is the only defect of concern.

4. Place the letter of the probable defect beside the corresponding SMA welding condition.

SMA WELDING CONDITION	PROBABLE DEFECT
a.____moisture in electrode coating	a. slag inclusion
b.____using a copper nickel electrode to weld nickel-chrome-iron base metal	b. crack c. porosity d. spatter
c.____arc length too long	e. burn through
d.____excessive current during welding of the root pass	
e.____excessive weaving	

5. Place the following steps in proper sequence for SMA welding.

a. post weld heat treatment
b. interpass cleaning
c. fit up
d. detergent clean parts and water rinse
e. weld beads 2 through 9
f. weld root pass
g. preheat

h. radiograph final weld
i. grind weld contour

6. Name the source(s) of the following welding fundamentals for SMA welding:
   a. heat source
   b. shielding
   c. filler material

MATERIALS

The following materials are required to support this module.

1. Welder's Goggles or Hoods (hand held face shields are ideal)
2. Temperature Measuring Devices (crayon or contact pyrometer)
3. Lab Coat or Apron or work clothes
4. Long sleeves
5. Welded samples made by oxyacetylene and shielded metal arc processes

Safety Precautions

Students/trainees should observe the following safety precautions during any visit to a welding shop:

a. Never look at a welding flame or electric arc without welder's goggles or hoods. (Note: sunglasses are inadequate to protect the eyes from intense light from welding.)
b. Wear long sleeves and either work clothes, lab apron, or coveralls..
c. Avoid stepping on hoses and cables.
d. Do not touch or adjust welding equipment unless requested to do so by the instructor or tour guide.
e. Do not touch pieces recently welded; they will probably be very hot.

1. Visit a Welding Shop Employing Oxyacetylene Welding

On initial arrival at the welding shop, the instructor or a welding shop member will probably guide the students/trainees on a tour of the shop and explain pertinent safety rules to be observed. Subsequently, students/trainees should observe oxyacetylene welding in progress and complete Data Table 28-2-1 in accordance with this procedure.

a. Observe oxyacetylene welding in progress using Table 28-2-5 as guidance. Do not yet review the corresponding welding procedure. Complete Sections A through E of Data Table 28-2-1.
b. In completing Sections A through E, the student/trainee may need to ask questions of the welding shop tour guide to obtain necessary information. In each such case, the student/trainee should determine whether the information is made

self-evident by items at the welding station other than the welding procedure. Leave blank any data point which depends solely on the welding procedure as the source of information.

c. Compare the welding procedure against the entries in Sections A through E of Data Table 28-2-1.

d. Answer the questions in Section F of Data Table 28-2-1.

2. Visit a Welding Shop Employing Shielded Metal Arc Welding

After being introduced to the shop environment, students/trainees should observe shielded metal arc welding and complete Data Table 28-2-2 in accordance with this procedure.

a. Obtain an SMA welding procedure that is in use and complete Section A of Data Table 28-2-2 from the content of the procedure using Table 28-2-5 as guidance.

b. Observe shielded metal arc welding in progress that is governed by the procedure used to complete Section A of Data Table 28-2-2 and check off each entry in Section A upon validating that the requirement is being met.

c. List in Section B of Data Table 28-2-2 any requirement that is not met. If all requirements are met, enter none.

d. Using welder's goggles or hood, observe the welder strike an electrode and burn that electrode. Answer the questions of Section C of Data Table 28-2-2 based on these observations.

e. Observe a 'stop' on the weld joint. Describe the appearance of the stop in Section D of Data Table 28-2-2.

f. If the coated electrodes are heated prior to use, observe the electrode oven and complete Section E of Data Table 28-2-2.

g. Determine if the ammeters and voltmeters are periodically calibrated for accuracy. Complete Section F of Data Table 28-2-2.

3. Compare Monitoring Techniques

a. Discuss in class the differences in monitoring techniques between procedure #1 and Procedure #2.

b. Identify advantages and disadvantages of each.

DATA TABLE

Data Table 28-2-1
Oxyacetylene Welding

A. Joint Design (Circle ones in use)

1. butt corner tee lap edge hardsurface

2. grooved squared

3. Backing Used: yes no

B. Base Metal

1. Material Type_____

2. Thickness_____

3. Backing Material Type_____

C. Filler Material

1. (Circle one) bare straight length rod
bare spooled rod
coated electrode
flux-cored spooled rod

2. Filler Material Type_____

3. Record Marking That is on the Filler Material_____

D. Welding Parameters

1. Position_____

2. Preheat Temperature_____

3. Nature of Flame_____

E. Techniques

1. Stringer or Weave Bead_____

2. Forehand or Backhand_____

3. Single or Multiple Pass_____

4. Distortion Control Techniques_____

5. Initial or Interpass Cleaning Method_____

6. Reverse Side Welding: yes no

F. Evaluation

1. Is filler material compatible with base material? if not, why not?

2. Did the oxyacetylene flame being used agree with the type of flame required by the procedure?

3. Compare the remaining data entries for Section A through E with the welding procedure. Do all entries agree with the procedure? List any differences and explain why there is a difference.

4. List each data point that depended solely on the procedure as the source of information. Describe what could be done for each to make the data self-evident to the observer. (Guidance: The welding procedure describes what should be done. The observer is noting what is actually being done.

The observer should be able to determine from the nature of observed items, marking or instrumentation that what is being done agrees with what is required to be done.)

5. List each inspection required by the welding procedure and for each name the type of defects the inspection is capable of detecting

DATA TABLE 28-2-2

Shielded Metal Arc Welding

A. Procedural Requirements:

Base material type and specification number.....

Welding process.....

Manual or machine.....

Position of welding.....

Filler metal specification number.....

Filler metal classification.....

Single or multiple pass.....

Welding current (AC or DC).....

Polarity.....

Welding progression.....

Cleaning.....

Root Treatment.....

Grinding (other than root).....

Preheat and interpass temperature.....

Post weld heat treatment.....

Welding Data

Pass No.	Electrode Size	Welding Current		Electrode Angle	Sketch the Joint Detail
		Amperes	Volts		

Inspections (enter "none" if none are required)

1. Root _____
2. Intermediate layers _____
3. Final weld _____

B. Differences between requirements and practice:

Requirements Not Met	Actual Practice
_____	_____
_____	_____
_____	_____

C. Observation of electrode arc and weld puddle.

1. Describe how weld arc length was maintained. List observed effects of differences in arc length.

D. Appearance of welding stop

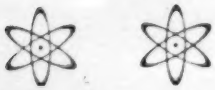
1. Contour _____
2. Pits _____

E. Electrode Oven

1. Are electrodes segregated by type _____
2. How is it known how long the electrodes have been in the oven.

F. Calibration Data

	Ammeter	Voltmeter
series number	_____	_____
frequency of calibration	_____	_____
date of last calibration	_____	_____
due date for calibration	_____	_____



REFERENCE MATERIALS

ASME, Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components, The American Society of Mechanical Engineers

ASME, Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications, The American Society of Mechanical Engineers

AWS, D1.1, Structural Welding Code, American Welding Society, Inc.

AWS, D1.2, Commentary on Structural Welding Code, American Welding Society, Inc.

ACROS, Welding Products, Pamphlet GC 47260, Acros Corporation, 1500 South 50th Street, Philadelphia, PA 19143

TEST

1. State the function of the following equipment used in oxyacetylene welding:
   a. torch

   b. pressure regulations

   c. needle valves

   d. bare rod

2. Name three types of oxyacetylene flames, describe how each is obtained, and how each is visually discernable.

3. Describe how an oxyacetylene welder controls the size of molten weld puddle.

4. Arrange the following steps of an oxyacetylene welding procedure into correct sequence.
   a. radiograph
   b. detergent clean and rinse
   c. weld root
   d. preheat
   e. weld subsequent passes
   f. fit-up

5. What is the type of fuel gas considered an essential variable of the oxyacetylene welding process?

6. State one probable cause of each of the following defects in a weld made by the oxyacetylene welding process:
   a. porosity
   b. underbead crack
   c. incomplete fusion

7. State the function of the following equipment used in the shielded metal arc welding process.
   a. electrode holder

   b. power source

   c. ground clamp

8. Name three functions of the coated electrode used in shielded metal arc welding.

9. Relate the terms "straight polarity" and "reverse polarity" as applied to shielded metal arc welding.

10. Why does the shielded metal arc welder attempt to maintain constant arc length?

11. Why is the type of electrode an essential variable in the shielded metal arc welding process?

12. State one probable cause of the following defects in a weld made by the shielded metal arc welding process.
    a. undercut

    b. porosity

    c. slag inclusion

    d. excessive splatter